Investigate naturalistic decision-making of a workgroup in dynamic situation. From the modelling to the design of a training virtual environment

Yohann Cardin, Cyril Bossard, Cédric Buche

Investigate naturalistic decision-making of a workgroup in dynamic situation. From the modelling to the design of a training virtual environment

Yohann CARDIN[a,c,d], Cyril BOSSARD[a,c] and Cédric BUCHE[b,c]
[a]*Centre de Recherche sur l'Éducation et la Didactique (EA 3875), Université Européenne de Bretagne, U.F.R Sport et EP de Brest*
[b]*Laboratoire en Sciences et Techniques de l'Information, de la Communication et de la Connaissance (CNRS-UMR 3192), École Nationale d'Ingénieurs de Brest*
[c]*Centre Européen de Réalité Virtuelle*
[d]*STDI*

ABSTRACT

This thesis aims to rely on a work of activity analysis to develop a virtual training platform for firefighters (SécuRéVi). The use of this type of simulation is more and more common in the field of training, but often suffers from a lack of credibility in terms of learning content and method. To solve this problem, this project aims to model the collaborative work of firefighters during training sessions in order to provide assistance to the development of SécuRéVi. The activity analysis of these group works, relying on the EAST (Event Analysis of System Teamwork) methodology and self-confrontation interviews, is expected to highlight the particular "know-how" and to develop pedagogical scenarios essential in the design of such a training platform.

KEYWORDS

Decision making; collaborative work; firefighter; virtual environment.

INTRODUCTION

This PhD work is at the intersection of the fields of ergonomics, occupational didactics and virtual reality. Its originality lies in the facts it etablishes a link between the field of activity analysis and the computerized design of a virtual environment for training.

All this work is part of a larger project between the European Center of Virtual Reality (ECVR) and STDI company, specialized in the production of books in any field and being open for the past few years to new learning methods based on multimedia technologies. It aims to formalize a generic methodology and operational design of virtual environment for human activity (VEHA) using the Mascaret platform while pursuing three main objectives: i) placing the training specialists (trainers, educationalists, teachers, experts) at the center of the design of the VEHA, ii) developing authoring tools allowing these professionals to bring their expertise without the intervention of a computer engineer iii) rationalizing the design process of the VEHA in order to reduce costs and capitalize on the developments of a project for another.

VIRTUAL ENVIRONMENT FOR HUMAN ACTIVITY (VEHA)

Simulation in virtual environment is emerging as a major and innovative technology in the field of training. However, these systems are considered complex because they involve a variety of components, structures and a diversity of interactions (Tisseau, 2001).

Among these systems, there are particularly VEHA which are defined as environments that interact human and artificial agents, and providing access to training resources in order to promote the construction of knowledge by the learner. This type of environment often relies on the implementation of pedagogical scenarios whose role is to provide instructions to individuals to ensure the smooth progress of the learning session. An example using this type of tool is a training virtual simulator of F-16 airplane engine maintenance (Fonseca, Paredes, Rafael Morgado & Martins, 2011). This environment has the characteristic to train team coordination through the use of sub-scripts (corresponding to each member's tasks) and a management component of all interpersonal relationships.

In the field of firefighters, a multitude of training simulators have been developed, and this in different topics. For example, Omodei, Elliott and Walshe (2004) conducted a critical review of literature on wildland firefighting simulators. Thus, they presented seven softwares for which they made a brief description and drew

H. Chaudet, L. Pellegrin & N. Bonnardel (Eds.). *Proceedings of the 11th International Conference on Naturalistic Decision Making (NDM 2013), Marseille, France, 21-24 May 2013*. Paris, France: Arpege Science Publishing. ISBN 979-10-92329-00-1

up the advantages and disadvantages of each one. Nevertheless, this review was more particularly based on the range of scenarios they are able to generate and all the control possibilities that they offer to the trainer.
SécuRéVi (Querrec, Buche, Maffre & Chevaillier, 2003) is another example of virtual platform using pedagogical scenarios, this in order to train firefighters to the procedures and operational management against fires with chemical risks. A distinctive feature of this simulator, developed in the ECVR and which the results of this thesis are intended for, is to rely on a generic "scenario creation" tool, independent of the type of task or the learning area (Marion, Querrec & Chevaillier, 2009).
Beyond any aesthetic aspect, the primary objective of such an environment is learning and knowledge acquisition by the learner. From this perspective then, Hall (2011) has attempted to measure the effects of computer-based simulation training on fire ground incident commander (IC) decision-making. The purpose of this study was to establish a correlation between the training program on the simulator called FLAME-SIM and increases in the decision-making efficiency of fire ground ICs. However, the improvement in the participants decision-making being only assessed on the simulator and finally, the interest of learning transfer from VEHA to the real field was missing from this study.
Another important point to consider in the perspective of a learning is that a simulator must have adequate levels of fidelity to both physically and psychologically (Omodei et al., 2004). Physical fidelity thus refers « to the extent to which the simulation is successful in reproducing the physical aspects of the environment » like the sounds, the fires' behaviours or the equipment available. For its part, the psychological fidelity refers to « the degree to which the simulation captures the functional and cognitive aspects of the performance domain » (Entin, Elliott & Schiflett, 2001). More precisely, a virtual environment in order to be credible have to place the same cognitive demands on participants' decision-making and thought processes as occurs in real situation. Thus, the scenarios generated by the program must provide sufficient physical fidelity to allow the required high-level psychological fidelity.
In this way, in this type of learning platform, collaboration between humans and/or virtual entities can be undermined when the task of modelling the collaborative activity is left to the sole discretion of the computer engineer (Tchounikine, Baker, Balacheff, Baron, Derycke, Guin, Nicaud & Rabardel, 2004). To resolve this problem, this thesis has the ambition to try to analyze, describe and modelize human collaborative activity in natural situations with the purpose of providing assistance to the design of training devices using new technologies.

DECISION-MAKING ANALYSIS IN THE FIELD OF FIREFIGHTERS

For over twenty years, models and concepts from the approach of Natural Decision-Making gained some influence as a method to explain the decision-making in many complex situations. NDM approach has accumulated observations in most of the major risk situations (driving, military, nuclear, medical emergencies, etc.)..
Thus, in 1986, Klein & Brezovic have developed the Recognition-Primed Decision (RPD) model in order to modelize the decisions of firefighter's officers in the management of serious incidents in a control center. From interviews with 26 experienced firefighter's officers, the authors analyzed the decisions made during 32 critical interventions by collecting verbal and behavioural data. This data analysis then showed that 80% of the decisions made by the officers were based on a process of recognition of typical situations. Expert officers then did not compare several options but perceived situations encountered as "typical cases" to which they associated certain types of actions (or sequence) appropriate and commonly used with success. In addition, they highlighted the fact that the first option considered by these experts often intuitively was usually satisfactory.
Other authors adhering to the NDM approach followed in the study of decision-making of firefighters. Thus McLennan and Omodei made various studies in this area, leading them to put forward some reflections on the use of the RPD model for unusual and complex events (McLennan, Pavlou & Omodei Klein, 2005). By the setting up of interviews of 40 experienced controllers, they also highlighted the different processes of anticipation used to better manage wildfires: "recognition", "extrapolation" and "construction". Processes that can be directly linked to the three forms of anticipation issued by Klein, Snowden & Pin (2007): "pattern matching", "trajectory tracking" and "convergence". In addition to these results, their studies have implemented many methodological innovations such as the introduction of cameras in the firefighter helmets to improve self-confrontation interviews (McLennan et al., 2005) or the creation of a Human Factors Interview Protocol (HFIP) guide (McLennan & Omodei Reynolds, 2005) to facilitate the detailed recall of decision-making process in fire management.
For his part, in a more theoretical approach, Rahman (2009) took an interest in the effect of emotion in decision-making under life threatening conditions thus highlighting the concept of emotion-primed NDM. This theoretical concept enabling to study the NDM under threat is based on "constructive" and "destructive" modulations to explain the enhancement or reduction of the probability of making a decision leading to a satisfying outcome under these conditions. In this way, he provided a framework for designers and trainers to better take into account the effect of emotion in the design of different training systems for decision-making.
Finally, in order to synthesize and bind all this findings, Pardue (2009) wrote a review of literature on risk behaviour and decision-making among firefighters with the aim to highlight all the possible ways of

improvement in pedagogical methods for initial training and continuing education in professional development. After identifying all external and internal factors that influence the decisions firefighters make on the ground, he insists on developing more exercises in unfamiliar situations of danger (most strongly associated with firefighter injuries and fatalities on the ground) setting up through pedagogical scenarios and enabling the protagonists' ratings in the various areas of learning. This type of training enabling to distinguish the combinations of fire ground factors that are only slightly dangerous from those considered deadly contrary to usual exercises in which the emphasis is on strategy and tactics.

However, all these studies focused more particularly on the decision-making of some individuals and how to train them. They did not really take into account the collaborative aspect of the firefighter job and the influence that can have on the decision-making of each one in dynamic situation. This problematic point is thus underlined by Fern, Trent and Voshell (2008) who base their opinion on a critique of the RPD model. For them, the latter only concerns the activity of a single person, not a whole team of which the dynamics should be taken into account. In addition, this model provides only how firefighters make their decisions but finally does not describe the specific cognitive work and the decisions required in the domain that can help for the design of training systems. To do this, they built their study on the Cognitive Task Analysis (CTA) which is not a single method of analysis but a set of techniques and methods classified as « formal analysis », « empirical techniques » and « computer models ». In this way, the authors rely especially on a functional goal decomposition of urban firefighting outlining the functions, decisions and information requirements of the firefighters on the ground. This led them to consider the difficulties of urban firefighter decision-making and the importance of improving communication systems within intervention teams.

In this purpose, a recent metholodogy called EAST (Event Analysis for Systemic Teamwork) emerged to study the group activity (Walker, Stanton, Stewart, Jenkins, Wells, Salmon & Baber, 2009).

EVENT ANALYSIS FOR SYSTEMIC TEAMWORK METHOD

EAST is a macro-ergonomic method developed by the HFI DTC (Human Factors Integration Defence Technology Center) and used for studying the command and control sociotechnical networks. It is a descriptive method which extracts large scale systems level data on the emergent properties of a sociotechnical network arising from interaction between its different components (humans or technical devices).

EAST method rests on the Distributed Situation Awareness (DSA) which is a systemic concept unlike the Situation Awareness concept which is only focused on the individual (Endsley, 1995). In a crisis situation, the performance of the network is directly linked to the quality of the DSA (Stewart, Stanton, Harris, Baber, Salmon, Mock, Tatlock, Wells & Kay, 2008). Concretely, the DSA takes into account the fact that there can be as many points of view of a situation as agents within it and particularly the relatively invariant element which is "information" and its distribution (implicit or explicit) by its different agents across the entire system (Stanton, Stewart, Harris, Houghton, Baber, McMaster, Salmon, Hoyle, Walker, Young, Linsell, Dymott & Green, 2006).

All of this allows EAST to model three networks which are the aim of the method (Figure 1) : Task, Social and Propositional (or Knowledge) networks. The task network is a chronological representation of performed operations showing "who" is performing "what", "when".The social network represents a modeling of the relationships between actors allowing to know who are the central agents within the system. Finally, the propositional network describes the interaction between agents and the knowledge objects to characterize the flow of information required to decision-making within the system.

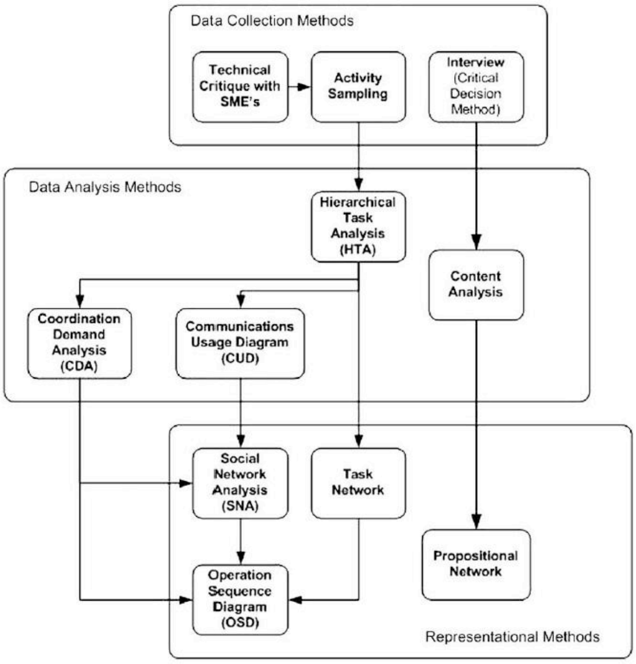

Figure 11. Structure of the EAST method (Walker et al., 2009)

This EAST method has already been used in various fields (fire service, air traffic control, military, police and so on) and allowed to obtain numerous information about the decision-making of individuals within collaborative situation. Thus, in the framework of our project this could represent an interesting method to set up (probably after some modifications to define in relation to our study) in order to collect essential data.

TOWARDS A COMBINED METHODOLOGY

As we have seen above, deal with the problem of agent activity within a group is very complex and needs to be able to rely on two approaches: psychological and systemic. Following this principle, the concepts of DSA and schema were discussed jointly by Stanton, Salmon, Walker and Jenkins (2009) so that it is more suitable for the study of situation awareness in collective environments. Thus, they studied an example taken in the UK energy distribution domain by linking the concept of genotpe and phenotype schemata with the DSA.

After that, several recent studies have used this type of methodology combining systemic and psychological approaches especially for accident analysis in different fields. Thus, Salmon, Read, Stanton & Lenné (2013) studied an incident with a semi-trailer truck that occured at rail level crossings on investigating systemic and psychological factors. The systemic analysis permited the study of interactions between the different composants involved in the situation. For that, they relied on the building of an "Accimap" (Rasmussen, 1997) summarizing all the decisions, actions and mistakes made within the different system levels (technical and operational management, physical processes and actor activities, local government, etc.). Their psychological approach relied on the schema theory and the Neisser's perceptual cycle (1976) to highlight the processes at the individual level. They used the Norman's taxonomy of schema-related slips errors (1981) which proposes that errors are caused by problems in the activation of schema that controls action sequences. In this way, they could find that the incident were caused by a truck driver mistake (more precisely, a faulty activation of schema error according to the Norman's taxonomy) maybe brought by some ambiguous environmental elements.

A lot of studies used the same methodology in others fields like aviation (Plant & Stanton, 2011) or public health incidents (Cassano-Piche, Vicente & Jamieson, 2009) for example. However, for their systemic approach, all of these studies used the Rasmussen's Accimap contrary to Stanton et al. (2009) who tried to link the concepts of genotype and phenotype schemata with a propositional networks on which is based the EAST method. In our project, the use of a propositional network, which can be moreover decomposed by indivual, seems to be more suitable for the transfer of agents' decision-making underlying processes on the ground to a virtual environment.

METHODS

The activity analysis during this thesis will take place during the training exercises for firefighters of Morbihan. This work will focus more particularly on one or several exercises performed in collaborative situation and requiring a global coordination and a decision-making from each member of the team under high time pressure.

Thus, this procedure might combine several methods to collect data. One of them is the EAST method described above. This method could give all the information used by the team members during the exercice and the dynamic of their flow during each phase of the training exercise. Particularly, this method will provide a propositional network which represents all the knowledge used by the agents on the ground (Figure 2).

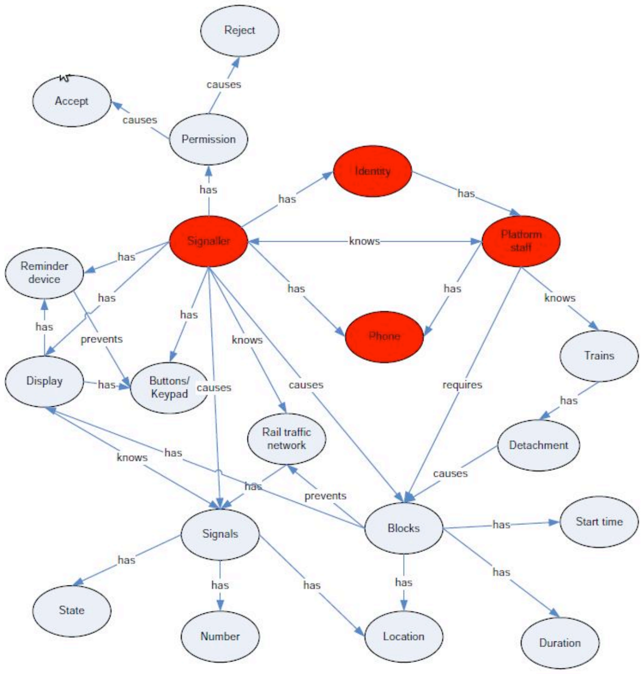

Figure 12. Example of Propositional Network (Gibson, Walker, Stanton & Baber, 2004)

This kind of network has the advantage to detail precisely and to link environmental cues and knowledge taken into account by agents to act, moreover in a dynamic way. Another big advantage is that these networks can be decomposed individually for each person involved in the exercise describing in this way the situation awareness of the individuals working in the system (Stanton et al., 2009).

This method could be completed by the setting up of self-confrontation interviews (Theureau , 2010) with each member in order to obtain verbalization data on their own decision-making. Thus this data, by a qualitative analysis based on the RPD model, might show us "how" the information is used by them at each step and if it forms a part of typical situation recognized.

These data could also be supplemented by information provided by trainers about their expectations regarding the knowledge acquired by the protagonists and their learning methods.

EXPECTED RESULTS AND PROSPECTS

The activity analysis of these work groups should contribute to highlight the particular "know-how". The latter should be able to define the autonomy area of each member of a team, the "possible violations" and acceptable practices in terms of safety. In all the studies, the management by individuals of their own resources is at the heart of the management of dynamic and collaborative situations. Here, the resources in question are not only "extrinsic" resources of the individuals (material and technical resources, organizational resources, human resources outside the system, etc.). Resources managed in natural situations are also "intrinsic" resources of the system operators. These immaterial resources cover the know-how, skills, cognitive resources, job rules, meta-knowledge, etc. (Falzon & Teiger, 1995). In the end, it is the extraction of these internal resources which should enable to contribute to the development of SécuRéVi and make all the interest of this work.

Indeed, firstly with a pedagogical point of view, the individual propositional networks obtained by the EAST method will supply all information (environmental cues or knowledge) that the VEHA users have to take into account at each phase of the exercise. Thus, we can imagine a virtual tutor which could automatically provide the information or highlight an environmental cue of which one user needs at a particular time. Secondly, with a computing point of view, the fact that propositional networks can be decomposed for each team member could normally allow to develop the processes which would direct all the virtual agents in the environment. Finally, the study of « how » information is used by each team member on the ground could help to enhance the artificial intelligence of virtual agents in order to be more credible.

By relying on all these results, we hope to design a credible VEHA that could be a real complement of the firefighters or incident commanders initial training.

REFERENCES

Cassano-Piche, A., Vicente, K., Jamieson, G. (2009) A test of Rasmussen's risk management framework in the food safety domain: BSE in the UK, *Theorical Issues in Ergonomics Science* 10 (4), 283-304.

Endsley, M. (1995) Toward a theory of situation awareness in dynamic systems, *Human Factors* 37 (1), 32–64.

Entin, E., Elliott, L. & Schiflett, S. (2001) DMT-RNet: An internet-based infrastructure for distributed multidisciplinary investigations of C2 performance, Proceedings of the 6th International Command and Control Research and Technology Symposium, Annapolis, MD.

Falzon, P. & Teiger, C. (1995) Construire l'activité, *Performances Humaines & Techniques, Hors Série (septembre)*, 34-39.

Fern, L., Trent, S. & Voshell, M. (2008) A functional goal decomposition of urban firefighting, *Proceedings of Information Systems for Crisis Response and Management (ISCRAM 2008),* Washington DC, May 4-7, 2008.

Fonseca, B., Paredes, H., Rafael, J., Morgado, L. & Martins, P. (2011) A Software Architecture for Collaborative Training in Virtual Worlds: F-16 Airplane Engine Maintenance, *In Proceedings of CRIWG*, 102-109.

Gibson, H., Walker, G., Stanton, N. & Baber, C. (2004) EAST Methodology for Railway Data: Protection Scenario, *Human Factors Integration Defence Technology Centre*.

Hall, K. (2010) The effect of computer-based simulation training on fire ground incident commander decision making, PhD dissertation, University of Texas at Dallas.

Klein, G. & Brezovic, C. (1986) Design engineers and the decision process: Decision strategies and human factors literature, *In Proceedings of the Human Factors and Ergonomics Society 30th Annual Meeting*, numéro 2, pages 771-775.

Klein, G., Snowden, D. & Pin, C. (2007) Anticipatory thinking. In K. Mosier & U. Fischer, (Eds.), *Proceedings of the 8th International Naturalistic Decision Making Conference,* 120-127, CA: San Francisco State University.

Marion N., Querrec R. & Chevaillier P. (2009) Integrating knowledge from virtual reality environments to learning scenario models. A meta-modeling approach, *International conference of Computer Supported Education,* pages 254--259, Lisbonne, Portugal.

McLennan, J., Pavlou, O., Klein, G. & Omodei, M. (2005) Using video during training to enhance learning of emergency incident command and control skills, *The Australian Journal of Emergency Management,* 20, 3, 10-14.

Mclennan, J., Elliot, G. & Holgate, A. (2009) Anticipatory thinking and managing complex tasks: Wildfire fighting safety and effectiveness, *In Proceedings of the Industrial & Organisational Psychology Conference,* pp. 90-95, Sydney, Australia.

Neisser, U. (1976) Cognition and Reality: Principles and Implications of Cognitive Psychology, Freeman, San Francisco.

Norman, D. (1981) Categorisation of action slips, *Psychological Review* 88 (1), 1-15.

Omodei, M., Elliott, G., Walshe, M. (2004) Development of computer simulated wildfire scenarios for the investigation of unsafe decision making, Bushfire Cooperative Research Centre Report 2: 2004. Melbourne, Victoria, Australia. 56 pp.

Pardue, J. (2009) Pedagogical reforms in firefighter education. Fire and Emergency Training Institute. http://www.feti.lsu.edu/archives/2009/OnlinePedogogicalReformsForFireFighterEducation.pdf.

Plant, K., Stanton, N. (2011) Why did the pilots shut down the wrong engine? Explaining errors in context using schema theory and the perceptual cycle model, *Safety Science* 50 (1), 300-315.

Querrec, R., Buche, C., Maffre, E. & Chevaillier, P. (2003) SécuRéVi : virtual environment for fire-fighting training. Dans Richir, S., Richard, P., et Taravel, B., éditeurs, *5th virtual reality international conference (VRIC'03)*, pages 169–175, Laval, France. ISBN : 2-9515730-2-2.

Rahman, M. (2009) Understanding naturalistic decision making under life threatening conditions, *Proceedings of the 9th International Conference on Naturalistic Decision Making* (pp. 121-128), Swindon, U.K.: The British Computer Society.

Rasmussen, J. (1997) Risk management in a dynamic society: a modelling problem, *Safety Science* 27 (2/3), 183-213.

Salmon, P., Read, G., Stanton, N. & Lenné, M. (2013) The Crash at Kerang: Investigating systemic and psychological factors leading to unintentional non-compliance at rail level crossings, *Accident Analysis and Prevention* 50, 1278-1288.

Stanton, N., Stewart, R., Harris, D., Houghton, R., Baber, C., McMaster, R., Salmon, P., Hoyle, G., Walker, G., Young, M., Linsell, M., Dymott, R. & Green, D. (2006) Distributed situation awareness in dynamic systems: theoretical development and application of an ergonomics methodology, *Ergonomics* 49(12–13), 1288–1311.

Stanton, N., Salmon, P., Walker, G., Jenkins, D. (2009) Genotype and phenotype schemata as models of situation awareness in dynamic command and control teams, *International Journal of Industrial Ergonomics* 39, 480-489.

Stewart, R., Stanton, N., Harris, D., Baber, C., Salmon, P., Mock, M., Tatlock, K., Wells, L. & Kay, A. (2008) Distributed situation awareness in an airborne warning and control system: application of novel ergonomics methodology, *Cognition Technology and Work,* 10 (3), pp. 221–229.

Tchounikine, P., Baker, M., Balacheff, N., Baron, M., Derycke, A., Guin, M., Nicaud, J. F. & Rabardel, P. (2004) PLaton-1: Quelques dimensions pour l'analyse des travaux de recherche en conception d'EIAH, Rapport technique, Rapport de l'action spécifique : Fondement théorique méthodologique de la conception d'EIAH, Département STIC du CNRS.

Theureau J. (2010) Les entretiens d'autoconfrontation et de remise en situation par les traces matérielles et le programme de recherche 'cours d'action', *Revue d'Anthropologie des Connaissances,* Volume 4, n° 2, 2010/2, 287-322, http://www.cairn.info/revue-anthropologie-des-connaissances-2010-2.html.

Tisseau, J. (2001) Réalité Virtuelle – autonomie in virtuo, Habilitation à diriger des recherches, Université de Rennes I.

Walker, G., Stanton, N., Salmon, P., Jenkins, D., Stewart, R. & Wells, L. (2009) Using an integrated methods approach to analyse the emergent properties of military command and control, *Applied Ergonomics,* 40 (4), pp. 636–647.